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[Name of Document] SPECIFICATION

[Title of the Invention] METHOD FOR MANUFACTURING FUEL CELL, AND  
ELECTRONIC DEVICE AND AUTOMOBILE INCLUDING THE FUEL CELL

[Claims]

[Claim 1]

A method for manufacturing a fuel cell, comprising the steps of:

forming first gas channels for supplying a first reactive gas on a first substrate;

forming a first current-collecting layer for collecting electrons generated through a  
reaction of the first reactive gas supplied through the first gas channels;

forming a first reacting layer for catalyzing the first reactive gas supplied through the first  
gas channels;

forming an electrolyte membrane;

forming second gas channels for supplying a second reactive gas on a second substrate;

forming a second current-collecting layer for supplying the electrons for a reaction of the  
second reactive gas supplied through the second gas channels; and

forming a second reacting layer for catalyzing the second reactive gas supplied through  
the second gas channels,

wherein, in at least one of the steps of forming the first and second gas channels, a gas  
channel formation material is coated on the substrate, using a discharger.

[Claim 2]

The method for manufacturing a fuel cell according to claim 1, wherein, in at least one of  
the steps of forming the first and second gas channels, the coatings are formed by repeatedly

applying the gas channel formation material, using the discharger, at predetermined intervals over the entire gas channel formation portion on the substrate.

[Claim 3]

The method for manufacturing a fuel cell according to claim 1 or 2, wherein, in at least one of the steps of forming the first and second gas channels,

the coated film is obtained by repeatedly applying the first gas channel formation material, using the discharger, at predetermined intervals over the entire gas channel formation portion, and

on the top of the coated film, coating is further performed with a second gas channel formation material having a lower viscosity than that of the first gas channel formation material.

[Claim 4]

The method for manufacturing a fuel cell according to any of claims 1-3, wherein a thermosetting resin or a photocurable resin is used as the gas channel formation material.

[Claim 5]

An electronic device comprising a fuel cell manufactured by the manufacturing method according to any of claims 1-4 as a power supply source.

[Claim 6]

An automobile comprising a fuel cell manufactured by the manufacturing method according to any of claims 1-4 as a power supply source.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a method for manufacturing a fuel cell in which different reactive gases are externally supplied to individual electrodes and are reacted to produce electricity based on the supplied reactive gases, and also relates to an electronic device and automobile including the fuel cell manufactured according to the method.

[0002]

[Prior Art]

Conventionally, known fuel cells include, for example, an electrolyte membrane, an electrode (anode) having a reacting layer on a surface of the electrolyte membrane, and another electrode (cathode) having another reacting layer made of, for example, platinum microparticles on the other surface of the electrolyte membrane. Among such fuel cells, for example, solid polymer electrolyte fuel cells use a solid polymer electrolyte membrane. On the anode side of a polymer electrolyte fuel cell, hydrogen splits into hydrogen ions and electrons. These electrons are conducted to the cathode side while the hydrogen ions travel through the electrolyte membrane to the cathode side. On the cathode side, the hydrogen ions combine with oxygen gas and the electrons to form water.

[0003]

Currently, micro fuel cells have been researched and developed for use in, for example, portable devices. The micro fuel cells have been manufactured by micro electro mechanical systems (MEMS), which are based on micromachining technology in, for example, semiconductor processes. An example of such methods includes forming a resist pattern on a substrate, etching other part to form gas channels except the resist pattern, and removing the resist resin (see Nonpatent Documents 1 and 2).

[0004]

[Nonpatent Document 1]

Sang-Joon J. Lee, Suk Won Cha, Amy Ching-Chien, Ryan O'Hayre, and Fritz B. Prinz,  
Factorial Design Study of Miniature Fuel Cells with Micromachined Silicon Flow Structures,  
The 200th Meeting of The Electrochemical Society, Abstract No. 452 (2001).

[Nonpatent Document 2]

Amy Ching-Chien, Suk Won Cha, Sang-Joon J. Lee, Ryan O'Hayre, and Fritz B. Prinz,  
Planar Interconnection of Multiple Polymer Electrolyte Membrane Micro Fabrication, The 200th  
Meeting of The Electrochemical Society, Abstract No. 453 (2001).

[0005]

[Problems to be Resolved by the Invention]

However, an expensive device is required to form gas channels on a substrate using technologies such as MEMS for semiconductor processes. In addition, such technologies unfortunately involve a complicated manufacturing process that includes patterning a resist resin, etching a substrate, and removing the resist resin.

In order to solve the above problems, the present invention provides a low-cost, simple, and efficient method for manufacturing a fuel cell including gas channels having an arbitrary pattern. The present invention further provides an electronic device and automobile including this fuel cell as a power supply source.

[0006]

[Means for Solving the Problems]

According to an intensive study on the above problems by the present inventors, gas channels having an arbitrary pattern can be easily and efficiently formed by applying a gas channel forming material onto a substrate using an inkjet discharger (hereinafter simply referred

to as "discharger").

[0007]

Thus, according to a first aspect of this invention, a method for manufacturing a fuel cell is provided with the steps of forming first gas channels for supplying a first reactive gas on a first substrate, forming a first current-collecting layer for collecting electrons generated through a reaction of the first reactive gas supplied through the first gas channels, forming a first reacting layer for catalyzing the first reactive gas supplied through the first gas channels, forming an electrolyte membrane, forming second gas channels for supplying a second reactive gas on a second substrate, forming a second current-collecting layer for supplying the electrons for a reaction of the second reactive gas supplied through the second gas channels, and forming a second reacting layer for catalyzing the second reactive gas supplied through the second gas channels, in which in at least one of the steps of forming the first and second gas channels, a gas channel formation material is coated on the substrate, using a discharger.

[0008]

According to the manufacturing method of this invention, it is preferable that in at least one of the steps of forming the first and second gas channels, the coatings are formed by repeatedly applying the gas channel formation material, using the discharger, at predetermined intervals over the entire gas channel formation portion on the substrate.

According to the manufacturing method, in at least one of the steps of forming the first and second gas channels, the coated film is obtained by repeatedly applying the first gas channel formation material, using the discharger, at predetermined intervals over the entire gas channel formation portion, and on the top of the coated film, coating is further performed with a second

gas channel formation material having a lower viscosity than that of the first gas channel formation material.

According to the manufacturing method of this invention, it is preferable that a thermosetting resin or a photocurable resin is used as the gas channel formation material.

[0009]

According to a second aspect of this invention, an electronic device is provided with a fuel cell manufactured by the manufacturing method as a power supply source.

According to a third aspect of this invention, an automobile is provided with a fuel cell manufactured by the manufacturing method as a power supply source.

[Detailed Description of the Invention]

[0010]

According to the manufacturing method of the present invention, gas channels having an arbitrary pattern can be easily formed on a substrate with a simple operation. In addition, a required amount of gas channel formation material can be precisely and efficiently applied over predetermined positions because this invention forms gas channels, using a discharger.

According to the manufacturing method of the present invention, gas channels having a uniform height and thickness can be efficiently formed by repeatedly applying the gas channel formation material at regular intervals, using the discharger.

According to the manufacturing method of the present invention, in at least one of the step of forming the first gas channels and the step of forming the second gas channels, after a coated film is obtained by repeatedly applying the first gas channel formation material, using the discharger, at regular intervals over the entire portion of gas channel formation on the substrate, if, on the top surfaces of the coated film, the first gas channel formation material may be further



coated with the second gas channel formation material having a lower viscosity than that of the first gas channel formation material to finish these top surfaces, gas channels having uniform thickness can be efficiently formed.

According to the manufacturing method of the present invention, a fuel cell including gas channels having desired patterns can be efficiently manufactured at low cost using a thermosetting resin or a photocurable resin, either of which is inexpensive and can be easily cured by heating or light irradiation, as a gas channel formation material.

[0011]

The electronic device according to the present invention includes a fuel cell manufactured by the manufacturing method of the present invention as a power supply source. This electronic device, therefore, can use environmentally friendly clean energy as a power supply source.

The automobile according to the present invention includes a fuel cell manufactured by the manufacturing method of the present invention as a power supply source. This automobile, therefore, can use environmentally friendly clean energy as a power supply source.

[0012]

[Embodiments]

A method for manufacturing a fuel cell, and an electronic device and an automobile including a fuel cell manufactured by this method will now be described in detail according to the present invention.

According to the present invention, the method for manufacturing a fuel cell includes the steps of forming the first gas channels for supplying first gas channels on a first substrate; forming a first current-collecting layer; forming a first reacting layer for catalyzing a first

reactive gas; forming an electrolyte membrane; forming second gas channels for forming the second gas channels on a second substrate; forming a second current-collecting layer; and forming a second reacting layer.

[0013]

This method may be performed with a fuel cell manufacturing equipment (a fuel cell manufacturing line) illustrated in Fig. 1. Referring to Fig. 1, this fuel cell manufacturing line includes dischargers 20a to 20k for use in individual steps, a belt conveyor BC1 linked with the dischargers 20a to 20j, a belt conveyor BC2 linked with the discharger 20k, a drive unit 58 for driving the belt conveyors BC1 and BC2, an assembler 60 for assembling a fuel cell, and a controller 56 for controlling the overall fuel cell manufacturing line.

[0014]

The dischargers 20a to 20j are aligned along the belt conveyor BC1 at regular intervals while the discharger 20k is disposed at a predetermined interval along the belt conveyor BC2. The controller 56 is connected to the dischargers 20a to 20j, the drive unit 58, and the assembler 60.

[0015]

In this fuel cell manufacturing line, the drive unit 58 drives the belt conveyor BC1 to convey a fuel cell substrate (hereinafter simply referred to as "substrate") to the dischargers 20a to 20j, which sequentially process this substrate. In response to a control signal from the controller 56, similarly, the belt conveyor BC2 is driven to convey a substrate to the discharger 20k, which is a processing in the discharger 20k. Based on the control signal from the controller 56, the belt conveyors BC1 and BC2 convey these substrates to the assembler 60. The assembler 60 assembles the substrates into a fuel cell.

[0016]

The dischargers 20a to 20k are inkjet dischargers, which are not particularly limited. Examples of the inkjet dischargers include thermal inkjet dischargers, which discharge droplets with bubbles caused by heating, and piezo inkjet dischargers, which discharge droplets with compression caused by a piezo element.

[0017]

Fig. 2 illustrates the discharger 20a in this embodiment. This discharger 20a includes a tank 30 for storing a discharging liquid 34, an inkjet head 22 linked to the tank 30 through a discharging liquid carrier pipe 32, a table 28 for holding and conveying a discharging liquid, a suction cap 40 for suctioning and removing an excessive discharging liquid 34 from the inkjet head 22, and an effluent tank 48 for storing the excessive discharging liquid suctioned by the suction cap 40.

[0018]

The tank 30 stores the discharging liquid 34, which is, for example, a gas channel formation material, and has a liquid level control sensor 36 for controlling a liquid level 34a of the discharging liquid in the tank 30. This liquid level control sensor 36 maintains a height difference  $h$  (hereinafter referred to as a waterhead value) between a tip end 26a of a nozzle-formed surface 26 of the inkjet head 22 and the liquid level 34a in the tank 30 within a predetermined range. For example, the discharging liquid 34 within the tank 30 can be fed into the inkjet head 22 with a pressure within a predetermined range by controlling the liquid level 34a to maintain the waterhead value within  $25 \text{ m} \pm 0.5 \text{ mm}$ . Such a pressure within a predetermined range allows the inkjet head 22 to discharge a required amount of discharging liquid 34 stably.

[0019]

The discharging liquid carrier pipe 32 has a discharging liquid passage portion earth joint 32a and a head portion bubble removal valve 32b. The discharging liquid passage portion earth joint 32a suppresses an electrical charge in the passage of the discharging liquid carrier pipe 32. The head portion bubble removal valve 32b is used when the suction cap 40 as described below suctions the discharging liquid 34 in the inkjet head 22.

[0020]

The inkjet head 22 includes a head body 24 and the nozzle-formed portion 26 having many nozzles for discharging the discharging liquid. A discharge liquid, for example, a gas passage formation material, etc. coated on the substrate when a gas passage for supplying a reactive gas is formed on a substrate is discharged from the nozzles of the nozzle formation surface 26.

The table 28 is movably arranged in a predetermined direction. This table 28 moves in a direction indicated by an arrow shown in the figure to hold the substrate conveyed by a belt conveyor BC1 and to introduce the substrate into the discharger 20a.

[0021]

The suction cap 40 is movable in a direction indicated by another arrow shown in Fig. 2. This suction cap 40 contacts the nozzle-formed portion 26 to surround the nozzles on the nozzle-formed portion 26. The suction cap 40 can thereby seal the nozzles in a space between the suction cap 40 and the nozzle-formed portion 26 to keep the nozzles away from outside air. That is, the suction cap 40 suctions the discharging liquid in the inkjet head 22 while the head portion bubble removal valve 32b is closed, and a discharging liquid does not flow from the tank

30 side. The suction cap 40, therefore, can suction the discharging liquid at a faster flow rate of a discharging liquid to be taken so as to exclude bubbles from the inkjet head 22 promptly.

[0022]

The suction cap 40 has a passage extending below. This passage has a suction valve 42, a suction pressure sensor 44, a suction pump 46, and the effluent tank 48. The suction valve 42 closes the passage to reduce the time required for balancing a pressure (atmospheric pressure) on the suction side below the suction valve 42 and a pressure on the inkjet head 22 side above the suction valve 42. The suction pressure sensor 44 detects abnormal suction. The suction pump 46 formed of, for example, a tube pump, suctions and conveys the discharging liquid 34, which is temporarily collected into the effluent tank 48.

[0023]

In this embodiment, although the dischargers 20b to 20k process different discharging liquids 34, the dischargers 20b to 20k are similar to the discharger 20a. Therefore, similar components in these dischargers are hereinafter indicated by the same reference numerals.

[0024]

The individual steps of a method for manufacturing a fuel cell on a fuel cell manufacturing line of Fig. 1 will now be described. Fig. 3 is a flowchart of a method for manufacturing a fuel cell on a fuel cell manufacturing line of Fig. 1.

[0025]

Referring to Fig. 3, according to the present invention, the method for manufacturing a fuel cell includes the steps of forming gas channels on a first substrate (S10, a first gas channel formation step); coating first support members in the gas channels (S11, a first support member coating step); forming a first current-collecting layer (S12, a first current-collecting layer

forming step); forming a first gas-diffusing layer (S13, a first gas-diffusing layer forming step); forming the first reacting layer (S14, a first reacting layer forming step); forming the electrolyte membrane (S15, an electrolyte membrane forming step); forming the second reacting layer (S16, a second reacting layer forming step); forming a second gas-diffusing layer (S17, a second gas-diffusing layer forming step); forming the second current-collecting layer (S18, a second current-collecting layer forming step); forming second support members (S19, a second support member coating step); and laminating the second substrate having the second gas channels formed (S20, an assembling step).

[0026]

(1) First gas channel formation step (S10)

Fig. 4 shows a first substrate 2, which is a rectangular silicon substrate. The substrate 2 is transferred to the discharger 20a by the belt converter BC1. The material for the first substrate 2 is not limited to silicon and may be alumina or another material normally used in fuel cells.

[0027]

The belt conveyor BC1 conveys this substrate 2 onto the table 28 of the discharger 20a, which introduces the substrate 2 into the discharger 20a.

The discharger 20a applies the gas channel formation material stored in the tank 30 of the discharger 20a onto predetermined positions of the top surface of the substrate 2 on the table 28 through the nozzles on the nozzle-formed portion 26. As a result, the top surface of the substrate 2 is coated with the gas channel formation material having a predetermined pattern. According to this embodiment, the discharger can easily coat the substrate with the gas channel formation material having an arbitrary pattern.

[0028]

The gas channel formation material is not particularly limited, but may be any material that can form the gas channels on the substrate. The present invention preferably uses synthetic resins, which have advantages such as high usability, strong adhesion to substrates, low cost, etc. Among synthetic resins, the present invention more preferably uses thermosetting resins or photocurable resins as the gas channel formation material for the fuel cell of the present invention. Thermosetting resins or photocurable resins, which are cured to form a three-dimensional network structure, excel in, for example, thermal resistance, chemical resistance, weather resistance, adhesion, wear resistance, waterproofness, mechanical strength, hardness, etc.

[0029]

Thermosetting resins refer to those that are heated alone or in combination with, for example, a curing agent to become a high polymer amount cross-linking body, which is an infusible and insoluble substance having a three-dimensional structure or a network structure.

[0030]

Examples of thermosetting resins include phenol resins, urea resins, melamine resins, furan resins, epoxy resins, unsaturated polyester resins, silicone resins, polyurethane resins, diallyl phthalate resins, guanamine resins, ketone resins, etc. On the other hand, examples of the curing agent used with thermosetting resin include aliphatic polyamines, amidoamines, polyamides, aromatic polyamines, acid anhydrides, Lewis bases, polymercaptans, etc.

[0031]

Typical photocurable resins are constituted by, for example, a photopolymerizable monomer or oligomer and a photoinitiator. A photocurable resin coating is irradiated with light

to excite the photoinitiator, which generates, for example, radical molecules and hydrogen ions. These radical molecules and hydrogen ions react with reactive groups of the monomer or oligomer to cause three-dimensional polymerization and cross-linking reaction, so that the coating becomes cured.

[0032]

Examples of the monomer include 2-ethylhexyl acrylate, 2-hydroxyethyl acrylate, neopentyl glycol diacrylate, hexanediol diacrylate, etc. On the other hand, the oligomer is a polymer (prepolymer) that has a double bond and in which the monomer is repeated about 2 to 20 times. Examples of the oligomer include polyester acrylate, epoxy acrylate, urethane acrylate, etc.

[0033]

Examples of the photoinitiator used for a photo-curing resin composition include benzophenone system compounds such as benzophenone, benzoin system compounds such as benzoin isopropyl ether, acetophenone system compounds such as acetophenone diethyl ketal, and thioxanthone system compounds such as chlorothioxanthone and isopropylthioxanthone.

[0034]

If the gas channel formation material to be used for this invention is a liquid, it may be used as-is. If it is not a liquid, the gas channel formation material may be dissolved in a suitable solvent to form a solution or may be dispersed in a suitable solvent to form a dispersion liquid. A thermosetting resin, for example, may be dissolved in an organic solvent or may be dispersed in an organic solvent, if desired, in combination with the curing agent in order to form a varnish. On the other hand, a photocurable resin composition used for the gas channel formation material constituted by, for example, the photopolymerizable monomer or oligomer,



the photoinitiator, etc. may be dissolved in an organic solvent to form a solution or may be dispersed in an organic solvent to form a dispersion liquid.

[0035]

The dissolved solvent or dispersed solvent for the thermosetting resin or the photocurable resin is not particularly limited, and conventionally known organic solvents may be used.

A variety of additives such as a stabilizer, a filler, a chain-transfer agent, a photosensitizer, and a cross-linking agent may be added to the varnish of the thermosetting resin or the solution or dispersion liquid of the photocurable resin to attain, for example, more stability, fortification, etc., as needed.

[0036]

The discharger 20a preferably coats the gas channel formation material at constant intervals over the predetermined areas of the top surface of the substrate 2. Referring to Fig. 5(a), the gas channel formation material is coated at equal intervals over the predetermined areas, on which the gas channels are formed, of the substrate 2. Referring to Fig. 5(b), the gas channel formation material is further coated at equal intervals into the gaps. Referring to Fig. 5(c), the gas channel formation material is further coated into the gaps. These operations are repeated to achieve uniform coatings, which, therefore, can provide gas channels having a uniform height and thickness (horizontal direction). In Figs. 5(a)-(c), circled numbers indicate the order in which the gas channel formation material is applied. 3a indicates a film coated with the gas channel formation material.

[0037]

This method is analogous to making tea. Teas having uniform strength can be made by putting tea leaves into a teapot, pouring hot water into the teapot, and repeatedly pouring a small

amount of tea into each cup at a time. Similarly, more uniform coatings, which provide fine gas channels having a more uniform height and thickness, can be formed by repeatedly coating the gas channel formation material at constant intervals than by sequentially applying the gas channel formation material from one side to the other direction. This is because the individual droplets of the gas channel formation material discharged by the discharger have errors in variable amounts and concentrations.

[0038]

Furthermore, in this invention, after coated films are formed by repeatedly applying the first gas channel formation material at predetermined intervals over the entire gas channel formation portion of the substrate 2 using the discharger, a second gas channel formation material whose viscosity is lower than that of the first gas channel formation material is preferably applied over the top surfaces of the coated films. The top surfaces of the coatings having microscopically nonuniform height formed by repeatedly applying the first gas channel formation material at predetermined intervals may be finished by applying the second gas channel formation material, which has lower viscosity and higher liquidity than that of the first gas channel formation material, to provide gas channels having a more uniform thickness. The first gas channel formation material, except that the fact that viscosity is low, may be used as the second gas channel formation material. The first gas channel formation material may be reduced in viscosity by, for example, reducing the solid concentration (by increasing the amount of solvent to be used).

[0039]

When a thermosetting resin or a photocurable resin is used as the gas channel formation material, the coated films of the gas channel formation material formed by the discharger are

cured by heating or light irradiation. The coated films may be heated or irradiated with light immediately after formation or in the subsequent step.

[0040]

Thermosetting resin coated film may be cured by heating at a predetermined temperature using, for example, a heater. The heating temperature and time required for completely curing the thermosetting resin coated films may be appropriately determined according to the types of thermosetting resin and curing agent used. On the other hand, photocurable resin may be cured by irradiation with light at a predetermined wavelength. Examples of the light used include ultraviolet light, visible light, electron beams, etc. In general, the light irradiation may be performed using lamps such as high-pressure mercury vapor lamps, metal halide lamps, etc. The photocurable resin composition are irradiated until they are cured, generally, for several seconds through several minutes.

[0041]

Thus, referring to Fig. 6, first gas channels 3 are formed in the gaps between gas channel formation layers 3b, which are solidified (or cured) coated films of the gas channel formation material.

[0042]

In this embodiment, the first gas channels 3 have the same width and are parallel to one side of the substrate 2. The first gas channels 3, however, may have, for example, any shape and channel width that allow the first reactive gas to flow through the first gas channels 3. For example, as shown in Figs. 7(a) and (b), the width of the first gas channels may increase continuously along the flow of the reactive gas from upstream to downstream. In general, the concentration of the reactive gas decreases according to the direction in which the reactive gas

flows. Thus, as shown in Figs. 7(a) and (b), if the width of the gas channel increases continuously along the flow of the reactive gas from upstream to downstream, the flow amount of the reactive gas increases according to the flow of the reactive gas. As a result, the reacting layer can receive a constant amount of reactive gas, which can provide a stable output for a fuel cell. In Figs. 7(a) and (b), arrows indicate supply ports for the first reactive gas.

[0043]

Subsequently, the table 28 delivers the substrate 2 having the gas channels to the belt conveyor BC1, which conveys the substrate 2 to the discharger 20b.

[0044]

## (2) First support member coating step (S11)

On the substrate 2 on which the first gas channels are formed, the first support members to support the first current-collecting layer are coated in the first gas channels 3. The table 28 holds the substrate 2 to introduce the substrate 2 into the discharger 20b. Then, from the discharger 20b, the first support member 4 stored in the tank 30 is emitted into the first gas channels formed in the substrate 2 through the nozzles of the nozzled form surface 26.

[0045]

The first support member is not particularly limited as long as it may be any material that is inert to the first reactive gas, suppresses the first current-collecting layer from falling into the first gas channels 3, and allows the first reactive gas to diffuse into the first reacting layer. Examples of the first support member includes carbon particles, glass particles, etc. This embodiment uses porous carbon having a particle diameter of about 1 to 5 microns. The support member made of such porous carbon with a predetermined diameter allow the reactive gas flowing through the gas channels 3 to diffuse upward through gaps in the porous carbon.

Thus, the flow of the reactive gas is not interfered. Fig. 8 shows an end face view of the substrate 2 having first support member 4 coated. The table 28 delivers the substrate 2 having the first support member 4 coated to the belt conveyor BC1, which conveys the substrate 2 to the discharger 20c.

[0046]

### (3) First current-collecting layer forming step (S12)

Next, the first current-collecting layer, which collects electrons generated through the reaction of the first reactive gas, is formed on the substrate 2. First, the belt conveyor BC1 conveys the substrate 2, which has been transferred to the discharger 20c onto the table 28, which introduces the substrate 2 into the discharger 20c. The discharger 20c applies a constant amount of current-collecting layer formation material stored in the tank 30 onto the substrate 2 through the nozzles on the nozzle-formed portion 26 to form the first current-collecting layer having a predetermined pattern.

[0047]

The current-collecting layer formation material may be any material that contains a conductive substance. Examples of the conductive substance include copper, silver, gold, platinum, aluminum, etc. These conductive substances may be used alone, or two or more substances may be combined. The current-collecting layer formation material may be prepared by dispersing at least one of these conductive substances in a suitable dispersing medium, if desired, adding a dispersant.

[0048]

This embodiment uses the discharger 20c to apply the current-collecting layer formation material. The discharger 20c can simply and accurately apply a predetermined amount to

predetermined positions. The discharger 20c, therefore, can largely save the consumption of the current-collecting layer formation material and efficiently form the first current-collecting layer having a predetermined pattern (shape). In addition, intervals for the application of the current-collecting layer formation material may be easily changed according to their positions so as to control the permeability of the reactive gas. Furthermore, different current-collecting layer formation materials may be freely changed according to the coated positions.

[0049]

Fig. 9 shows an end face view of the substrate 2 having first current-collecting layers 6 formed. As shown in Fig. 9, the first support members 4 support the first current-collecting layers 6, so the first current-collecting layers 6 do not fall into the first gas channels 3 formed on the first substrate 2. The table 28 delivers the substrate 2 having the first current-collecting layer 6 formed to the belt conveyor BC1, which conveys the substrate 2 to the discharger 20d.

[0050]

#### (4) First gas-diffusing layer forming step (S13)

Next, the first gas-diffusing layer is formed on the current-collecting layer of the substrate 2. First, the belt conveyor BC1 conveys the substrate 2, which has been transferred to the discharger 20d onto the table 28, which introduces the substrate 2 into the discharger 20d. The discharger 20d applies a gas-diffusing layer forming material stored in the tank 30 of the discharger 20d over predetermined positions of the top surface of the substrate 2 mounted on the table 28 through the nozzles of the nozzle-formed portion 26 to form the first gas-diffusing layer.

[0051]

Examples of the gas-diffusing layer forming material include carbon microparticles, which are typically used, carbon nanotubes, carbon nanophones, fullerene, etc. In this

embodiment, for example, the gas-diffusing layer, which is formed by using the discharger 20d, may have larger intervals between application (several 10  $\mu\text{m}$ ) on the current-collecting layer side and smaller intervals between application (several 10 nm) on the surface side. Thus, the larger intervals between applications provide wider channel width near the substrate to minimize the diffusion resistance of the reactive gas. On the other hand, the smaller intervals between applications near the reacting layer (near the surface side of the gas-diffusing layer) provide uniform and fine channels to easily form a gas-diffusing layer. The gas-diffusing layer may be made of carbon microparticles near the substrate of the gas-diffusing layer and the surface side may use a material with a low gas diffusing performance capability and an excellent catalyst holding performance capability.

[0052]

Fig. 10 shows an end face view of the substrate 2 having a first gas-diffusing layer 8 formed. As shown in Fig. 10, the first gas-diffusing layer 8 is formed entirely over the substrate 2 so as to cover the first current-collecting layer 6 formed on the substrate 2. The table 28 delivers the substrate 2 having the first gas-diffusing layer 8 formed to the belt conveyor BC1, which conveys the substrate 2 to the discharger 20e.

[0053]

#### (5) First reacting layer forming step (S14)

The first reacting layer is formed on the substrate 2 and electrically connected to the first current-collecting layer through the first gas-diffusing layer 8.

First, the belt conveyor BC1 conveys the substrate 2 onto the table 28, which introduces the substrate 2 into the discharger 20e. Within the discharger 20e, while inert gas is allowed to flow through the gas channels, the reacting layer forming material is applied onto the first gas-

diffusing layer 8 to form a first reacting layer 10. That is, the discharger 20e applies a reacting layer forming material stored within the tank 30 of the discharger 20c over predetermined positions of the top surface of the substrate 2 mounted on the table 28 through the nozzles on the nozzle-formed portion 26. The reacting layer forming material applied is heated at a predetermined temperature to form the reacting layer.

[0054]

Examples of the reacting layer forming material to be used include (a) a dispersion liquid of a metal carrier carbon of a metallic compound or a metal hydroxide absorbed by a carbon carrier, (b) a dispersion liquid of metal microparticles absorbed by a carbon carrier, etc.

[0055]

A method for preparing the dispersion liquid (a) will now be described. First, an aqueous or aqueous/alcoholic dispersion liquid of a metallic compound is prepared. If necessary, an alkali is added to the dispersion liquid to prepare a metal hydroxide. A carbon carrier such as carbon black is then added to the dispersion liquid, which is heated and mixed to allow the carbon carrier to absorb (deposit) the metallic compound or metal hydroxide, providing a crude metal-supported carbon. This crude metal-supported carbon is properly repeatedly filtered out, cleansed, and dried to refine the crude metal-supported carbon. The refined metal-supported carbon is dispersed in water or an aqueous alcoholic dispersing medium to provide the dispersion liquid. Examples of the metallic compound include precious metal salts such as platinum salts, gold salts, etc.

[0056]

Furthermore, the dispersion liquid (b) may be prepared by adding a carbon carrier to a dispersion liquid of metal microparticles with an organic dispersant. The metal microparticles



to be used are not particularly limited and may be of any metal that can catalyze the first and second reactive gases. Examples of the metal microparticles include microparticles of one or more kinds of metals selected from the group consisting of platinum, rhodium, ruthenium, iridium, palladium, osmium, and alloys of at least two of these metals. Among them, platinum microparticles are particularly preferred. The particle diameter of the metal microparticles, though not being particularly limited, ranges normally from 1 nm to 100 nm, preferably from several nm to several 10 nm. The organic dispersant is not particularly limited and may be any one that can uniformly disperse the metal microparticles in the dispersion liquid. Examples of the organic dispersant include alcohols, ketones, esters, ethers, hydrocarbon, aromatic hydrocarbons, etc.

[0057]

By using the discharger 20c, if the dispersion liquid (a) is used after coating the reacting layer forming material to form a coated film of the reacting layer forming material, the coating is dried, reduced with, for example, hydrogen gas, and further heated to form the reacting layer. On the other hand, if the dispersion liquid (b) is used, the coated film is heated to remove the organic dispersant and the dispersing medium, providing the reacting layer. This coated film may be fired at 200°C to 300°C in an atmosphere of an inert gas such as nitrogen gas. Then, the organic dispersant is sintered to form carbon microparticles, which adhere to the metal microparticles in the reacting layer.

[0058]

Fig. 11 shows an end face view of the substrate 2 having the first reacting layer 10. The table 28 delivers the substrate 2 having the first reacting layer 10 to the belt conveyor BC1, which conveys the substrate 2 to the discharger 20f.

[0059]

(6) Electrolyte membrane forming step (S15)

The electrolyte membrane is formed on the first reacting layer 10 of the substrate 2. First, the belt conveyor BC1 conveys the substrate 2, which has been transferred to the discharger 20f of onto the table 28, which introduces the substrate 2 into the discharger 20f. The discharger 20f applies an electrolyte membrane forming material stored within the tank 30 onto the first reacting layer 10 through the nozzles on the nozzle-formed portion 26 to form an electrolyte membrane 12.

[0060]

An example of the electrolyte membrane forming material to be used is a ceramic solid electrolyte, such as tungstophosphoric acid and molybdophosphoric acid, having a predetermined viscosity (for example, 20 cP or less). Another example is a polyelectrolyte, such as Nafion (made by DuPont), provided through the micellisation of perfluorosulfonic acid in a mixed solution of water and methanol in the weight ratio of 1:1.

[0061]

Fig. 12 shows an end face view of the substrate 2 having the first reacting layer 10 on which the electrolyte membrane 12 with a predetermined thickness is formed. The table 28 delivers the substrate 2 having the electrolyte membrane 12 to the belt conveyor BC1, which conveys the substrate 2 to the discharger 20g.

[0062]

(7) Second reacting layer forming step (S16)

The second reacting layer is formed on the electrolyte membrane 12 of the substrate 2. First, the belt conveyor BC1 conveys the substrate 2, which has been transferred to the

discharger 20g onto the table 28, which introduces the substrate 2 into the discharger 20g. In the discharger 20g, the second reacting layer is formed through the same process as in the discharger 20e. A second reacting layer forming material may also be the same as the first reacting layer forming material.

[0063]

Fig. 13 shows an end face view of the substrate 2 having the electrolyte membrane 12 on which a second reacting layer 10' is formed. This second reacting layer 10' catalyzes the second reactive gas. If, for example, the second reactive gas is oxygen gas, the reaction  $1/2O_2 + 2H^+ + 2e^- \rightarrow H_2O$  occurs in the second reacting layer 10'. The table 28 delivers the substrate 2 having the second reacting layer 10' to the belt conveyor BC1, which conveys the substrate 2 to the discharger 20h.

[0064]

#### (8) Second gas-diffusing layer forming step (S17)

The second gas-diffusing layer is formed on the second reacting layer 10' of the substrate 2. First, the belt conveyor BC1 conveys the substrate 2, which has been transferred to the discharger 20h onto the table 28, which introduces the substrate 2 into the discharger 20h. In the discharger 20h, the second gas-diffusing layer is formed through the same process as in the discharger 20d. A second gas-diffusing layer forming material may also be the same as the first gas-diffusing layer forming material.

[0065]

Fig. 14 shows an end face view of the substrate 2 having a second gas-diffusing layer 8'. The table 28 delivers the substrate 2 having the second gas-diffusing layer 8' to the belt conveyor BC1, which conveys the substrate 2 to the discharger 20i.

[0066]

(9) Second current-collecting layer forming step (S18)

The second current-collecting layer is formed on the second gas-diffusing layer 8' of the substrate 2. First, the belt conveyor BC1 conveys the substrate 2, which has been transferred to the discharger 20i onto the table 28, which introduces the substrate 2 into the discharger 20i. The second current-collecting layer 6' is formed on the second gas-diffusing layer 8' through the same process as in the discharger 20c. A second current-collecting layer formation material may also be the same as the first current-collecting layer formation material. The table 28 delivers the substrate 2 having the second current-collecting layer 6' to the belt conveyor BC1, which conveys the substrate 2 to the discharger 20j.

[0067]

(8) [Sic. 10] Second support member forming step (S19)

Next, the belt conveyor BC1 conveys the substrate 2 which has been transferred to the discharger 20j onto the table 28, which introduces the substrate 2 into the discharger 20j. The second support members are formed through the same process as in the discharger 20b. A second support material may also be the same as the first support material.

[0068]

Fig. 15 shows an end face view of the substrate 2 having a second current-collecting layer 6' and second support members 4'. On the second current-collecting layer 6', the second support members 4' are positioned such that the second support members 4' can be accommodated in the second gas channels formed on the second substrate for lamination with the substrate 2.

[0069]

(9) [Sic. 11] Second substrate assembling step (S20)

The substrate 2 having the second support members 4' is laminated with the second substrate having the second gas channels 3' separately prepared. The substrate 2 (first substrate) and the second substrate are laminated as the second support members 4' formed on the substrate 2 are joined so as to be housed within the second gas channels 3' formed on the second substrate. The second substrate may be the same as the first substrate 2. In the discharger 20k, the second gas channels are formed through the same process as in the discharger 20a.

[0070]

Thus, a fuel cell having a structure shown in Fig. 16 may be manufactured. In the fuel cell shown in Fig. 16, the substrate 2' is arranged so that the first gas channels 3, which are U-shaped and extend from one side to another side of the substrate 2, are parallel to the second gas channels 3' formed on the substrate 2'.

[0071]

According to this embodiment, a gas channel formation material may be applied onto a substrate with a discharger to form gas channels having desired patterns easily. The manufacturing method of this embodiment is particularly preferred to form gas channels having a fine structure on the substrate.

According to this embodiment, the discharger may repeatedly apply the gas channel formation material at predetermined intervals, thus easily forming gas channels having a uniform height and thickness.

According to this embodiment, the gas channels are formed on the substrate. The substrate, therefore, may be thin and made of various materials such as metal, silicon, synthetic resins, ceramics, and etc.

[0072]

Furthermore, according to this embodiment, dischargers are used in every step of forming the first gas channels; forming the first current-collecting layer; forming the first reacting layer; forming the electrolyte membrane; forming the second gas channels; forming the second current-collecting layer; and forming the second reacting layer. This embodiment, therefore, does not require MEMS (Micro Electro Mechanical Systems) for a semiconductor manufacturing process and provides a low-cost method for manufacturing a fuel cell.

[0073]

The method for manufacturing a fuel cell in this embodiment uses the dischargers in all steps. In this manufacturing method, while the dischargers are used in the steps of forming the gas channels on the substrates, the other steps may be the same as conventional methods for manufacturing a fuel cell. Such a modification also does not require the MEMS to form the reacting layers, so the method can provide manufacturing a fuel cell at low cost.

[0074]

In the manufacturing method of this embodiment, the individual components of the fuel cell are sequentially formed on the first substrate to which the first reactive gas is supplied. This first substrate is finally laminated with the second substrate to manufacture a fuel cell. The components may be sequentially formed on the substrate to which the second reactive gas is supplied.

[0075]

In the manufacturing method of this embodiment, the second support members are formed along the first gas channels on the first substrate so as to be coated. The second support members may be formed across the first gas channels so as to be coated. That is, for example, the second support members may be perpendicular to the gas channels on the first substrate so as to be coated. In this case, a fuel cell structure is obtained in which the second substrate is arranged so that the second gas channels of the second substrate are perpendicular to the first gas channels of the first substrate.

[0076]

In the manufacturing method of this embodiment, the first current-collecting layer, the first reacting layer, the electrolyte membrane, the second reacting layer, and the second current-collecting layer are sequentially formed on the first substrate having the first gas channels formed. A fuel cell can be manufactured as current-collecting layer, a reacting layer, and an electrolyte membrane may be formed on each of the first substrate and the second substrate before the first substrate and the second substrate are joined.

[0077]

As another aspect of a fuel cell manufacturing line in this embodiment, a first manufacturing line in which processing is performed for a first substrate and a second manufacturing line in which processing is performed for a second substrate are arranged; thus, this type of manufacturing line can be used in which processing in each manufacturing line is performed parallel to each other. In this case, the first and second substrates can be processed in parallel to manufacture a fuel cell promptly.

[0078]

The electronic device of the present invention includes the fuel cell described above as a power supply source. Examples of the electronic device include cell phones, personal handyphone systems (PHS), mobile, notebook PCs, personal digital assistants (portable information terminals), portable TV phones, etc. The electronic device of the present invention may have other functions such as games, data communications, recording/reproduction dictionaries, etc.

The electronic device of the present invention, therefore, can use environmentally friendly clean energy as a power supply source.

[0079]

The automobile of the present invention includes the fuel cell described above as a power supply source. According to the manufacturing method of the present invention, a plurality of fuel cells may be further laminated to manufacture a large fuel cell. That is, referring to Fig. 17, gas channels are formed on the reverse surface of the substrate 2' of the manufactured fuel cell, and on the reverse surface of the substrate 2' on which the gas channels are formed, fuel cells are laminated as gas-diffusing layers, reacting layers, an electrolyte membrane, etc. may be formed to manufacture a large fuel cell in the same manner as the manufacturing steps of the above-mentioned method of manufacturing a fuel cell.

The automobile of the present invention, therefore, can use environmentally friendly clean energy as a power supply source.

[Brief Description of the Drawings]

Fig. 1 exemplifies a fuel cell manufacturing line according to an embodiment.

Fig. 2 is a schematic illustration of an inkjet discharger according to this embodiment.

Fig. 3 is a flowchart of a method for manufacturing a fuel cell according to this



embodiment.

Fig. 4 is an end surface view of a substrate in a process of manufacturing a fuel cell according to this embodiment.

Figs. 5 (a) (b) and (c) show diagrams explaining a method of forming gas channels according to this embodiment.

Fig. 6 is a diagram explaining a process of forming gas channels according to this embodiment.

Figs. 7 (a) and (b) show top views of gas channels having different patterns according to this embodiment.

Fig. 8 is an end face view of a substrate in a process of manufacturing a fuel cell according to this embodiment.

Fig. 9 is an end face view of a substrate in a process of manufacturing a fuel cell according to this embodiment.

Fig. 10 is an end face view of a substrate in a process of manufacturing a fuel cell according to this embodiment.

Fig. 11 shows a state before and after a coated film of a dispersion liquid is formed and a reacting layer is formed.

Fig. 12 is an end face view of a substrate in a process of manufacturing a fuel cell according to this embodiment.

Fig. 13 is an end face view of a substrate in a process of manufacturing a fuel cell according to this embodiment.

Fig. 14 is an end face view of a substrate in a process of manufacturing a fuel cell according to this embodiment.

Fig. 15 is an end face view of a substrate in a process of manufacturing a fuel cell according to this embodiment.

Fig. 16 is an end face view of substrate in a process of manufacturing a fuel cell according to this embodiment.

Fig. 17 is a large fuel cell in which fuel cells are laminated according to this embodiment.

**[Explanation of the Symbols]**

- 2: First substrate
- 2': Second substrate
- 3: First gas channel
- 3': Second gas channel
- 3a: Coated film of gas channel formation material
- 3b and 3b': Gas channel formation material layers
- 4: First support member
- 4': Second support member
- 6: First current-collecting layer
- 6': Second current-collecting layer
- 8: First gas-diffusing layer
- 8': Second gas-diffusing layer
- 10: First reacting layer
- 10': Second reacting layer
- 12: Electrolyte membrane
- 20a-20k: Dischargers
- 56: Controller

**58: Drive unit**

**BC1 and BC2: Belt conveyors**

[Document]

## ABSTRACT

[Abstract]

[Object]

To provide a simple and efficient method for manufacturing a fuel cell having an arbitrary pattern with gas channels and an electronic device and an automobile including the fuel cell as a power supply source.

[Solving Means]

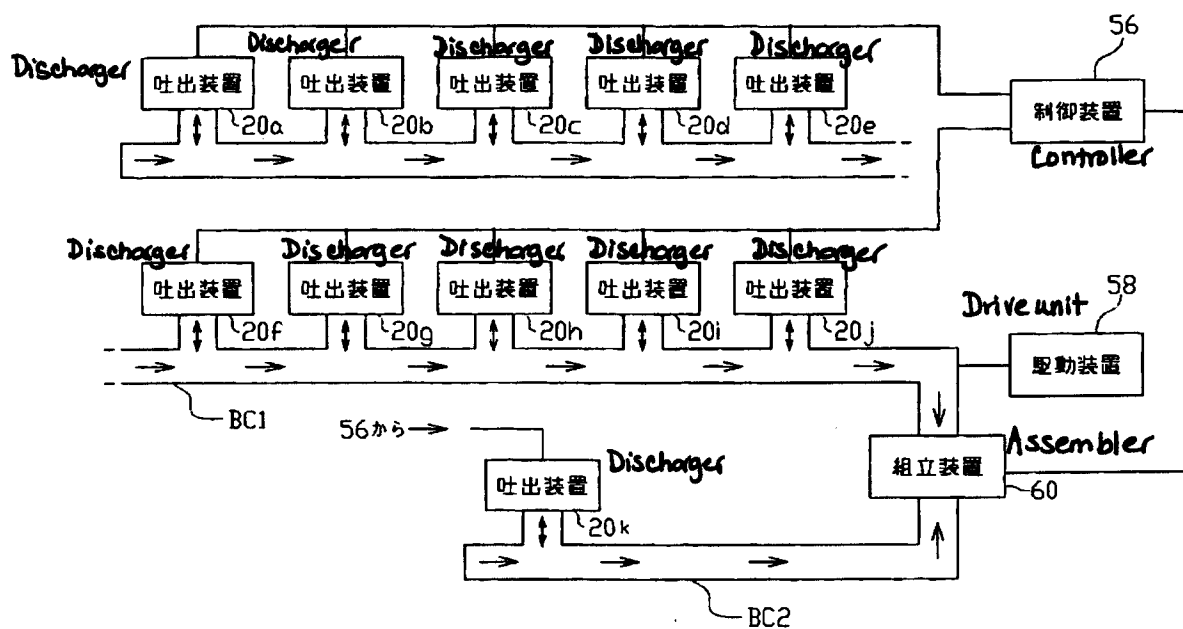
A method for manufacturing a fuel cell includes the steps of forming first gas channels on a first substrate; forming a first current-collecting layer; forming a first reacting layer; forming an electrolyte membrane; forming second gas channels on a second substrate; forming a second current-collecting layer; and forming a second reacting layer. In at least one of the steps of forming the first and second gas channels, the gas channels are formed by applying a gas channel formation material on the substrate, using a discharger. A fuel cell manufactured by this method is included in an electronic device and an automobile as a manufactured fuel cell is provided as a power supply source.

[Selected Figure]

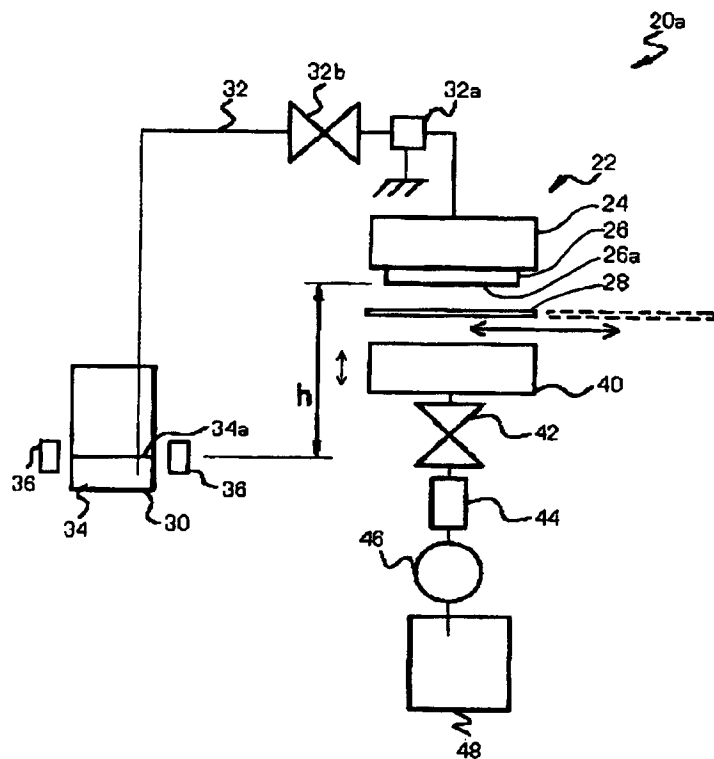
Fig. 6

【書類名】 図面

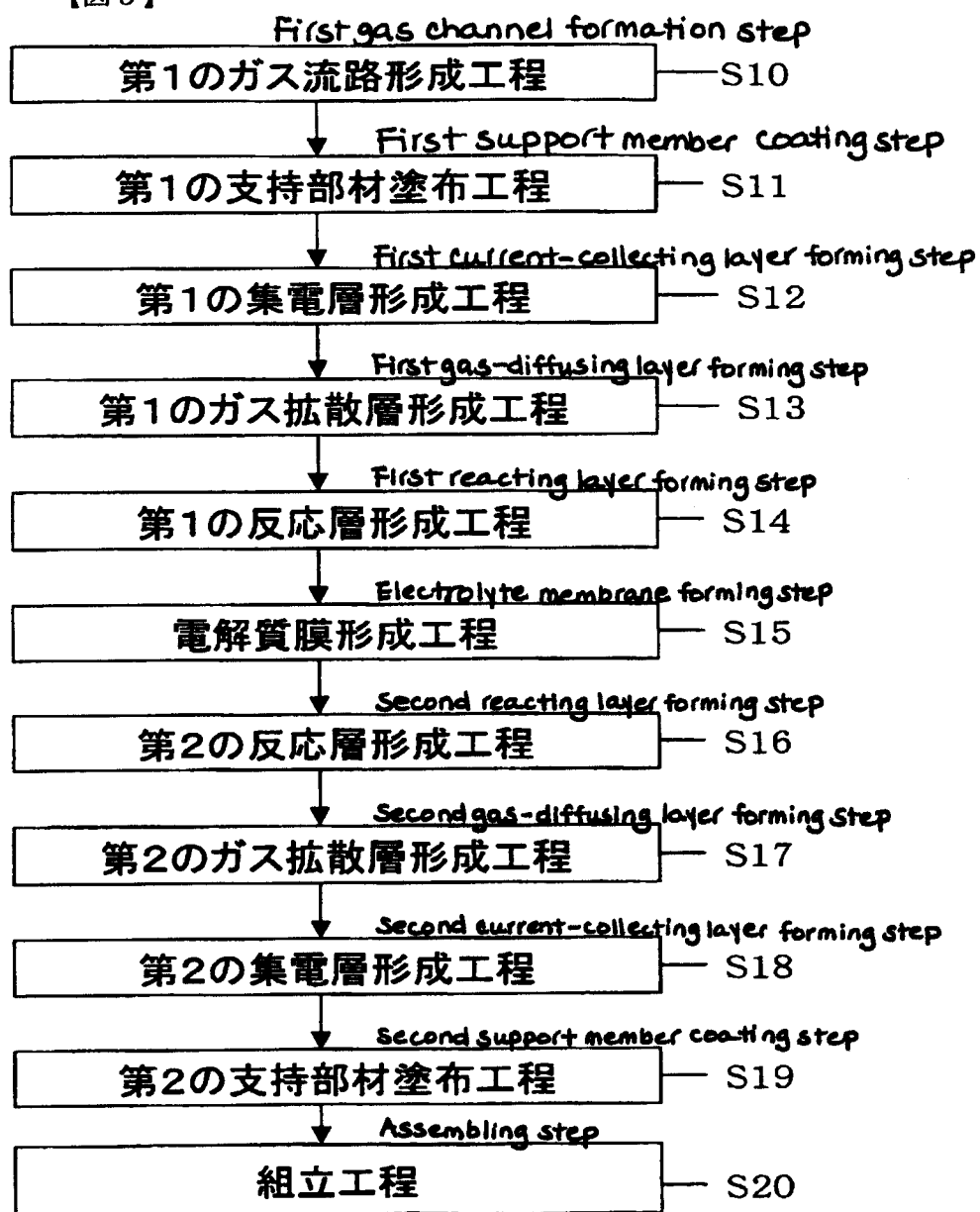
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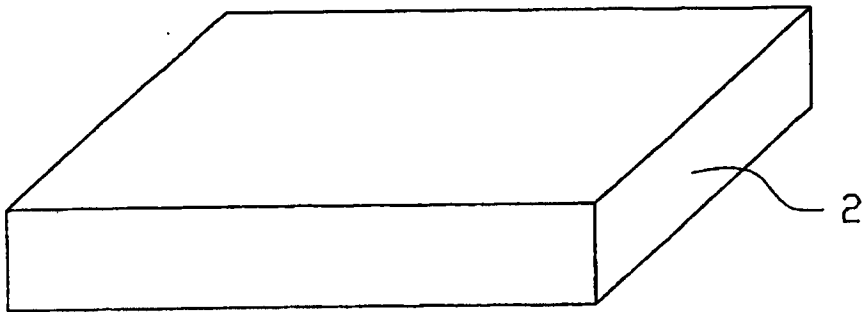
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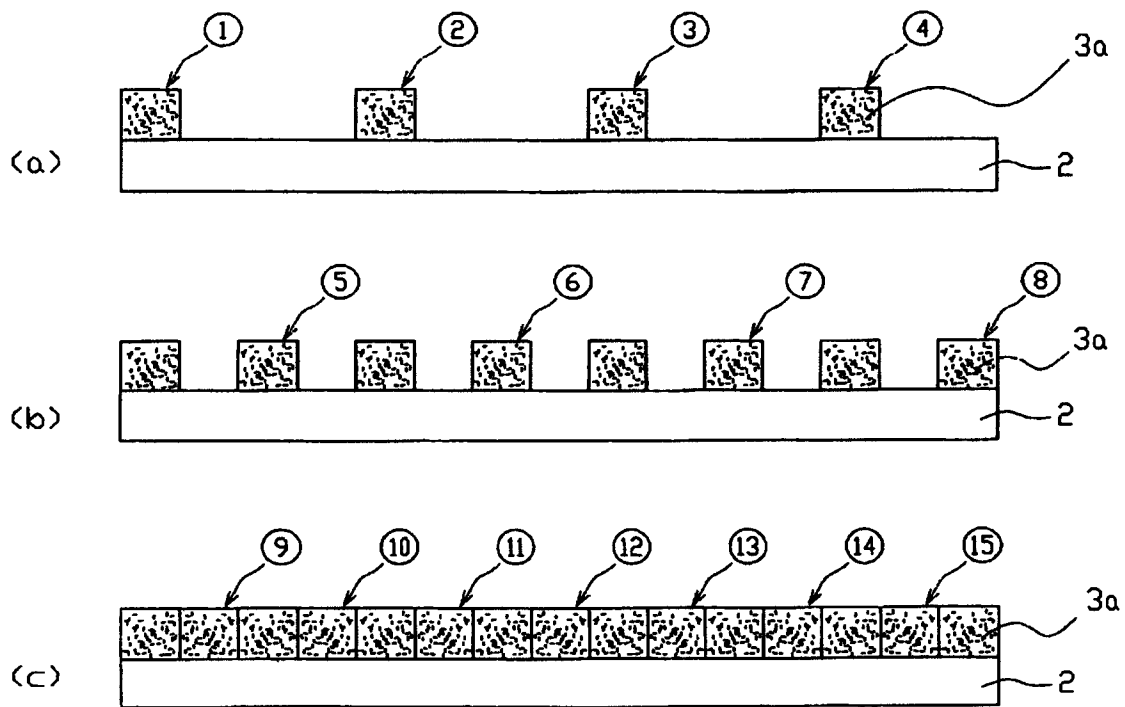
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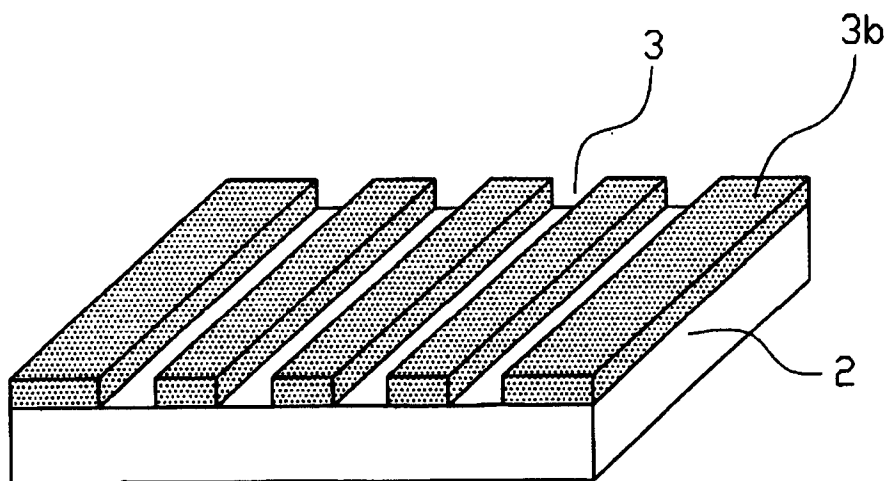
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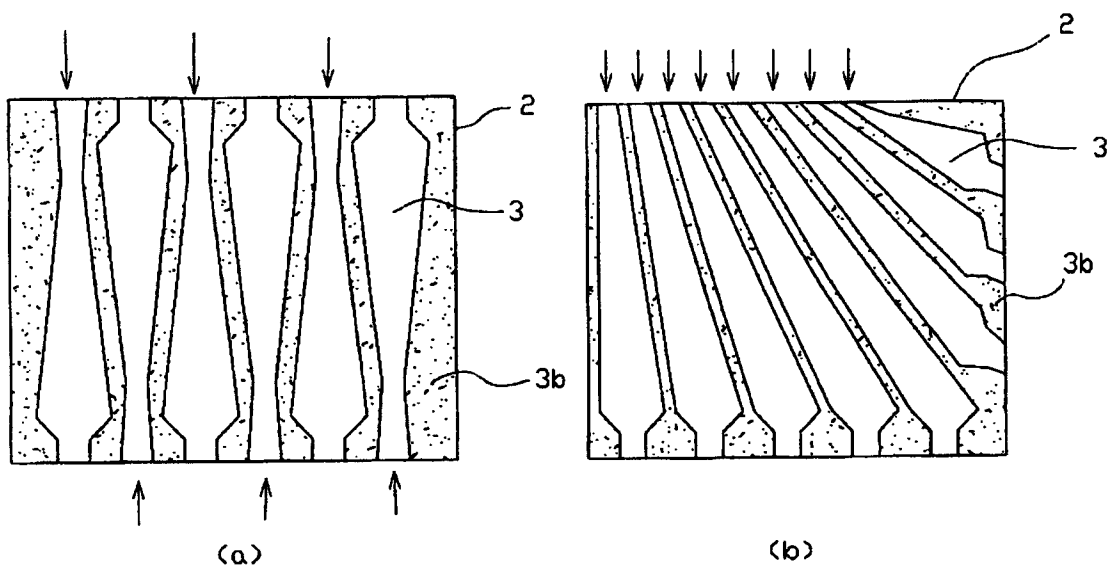
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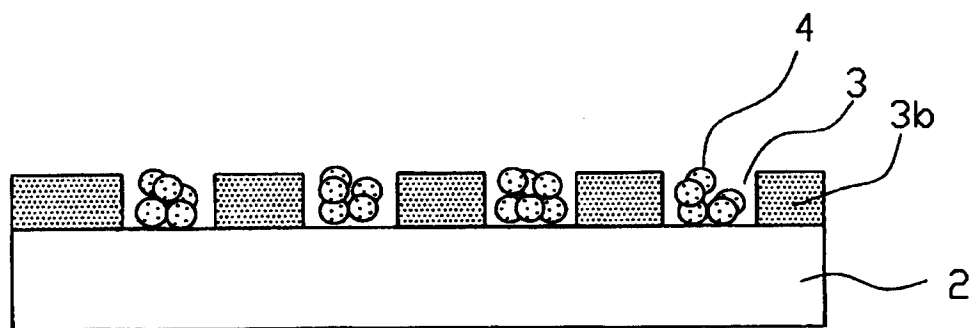
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【図 7】

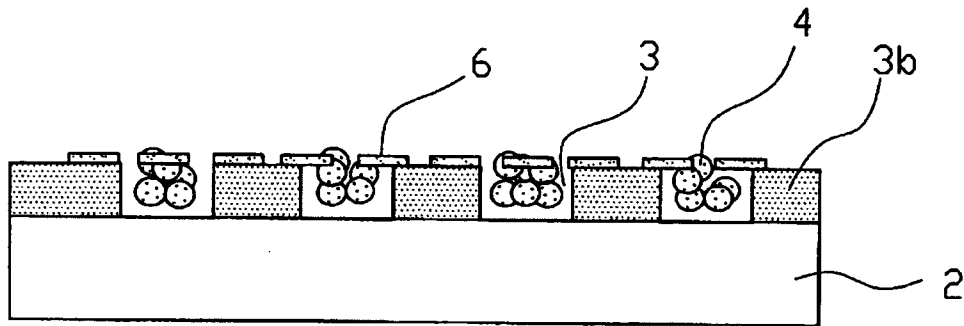


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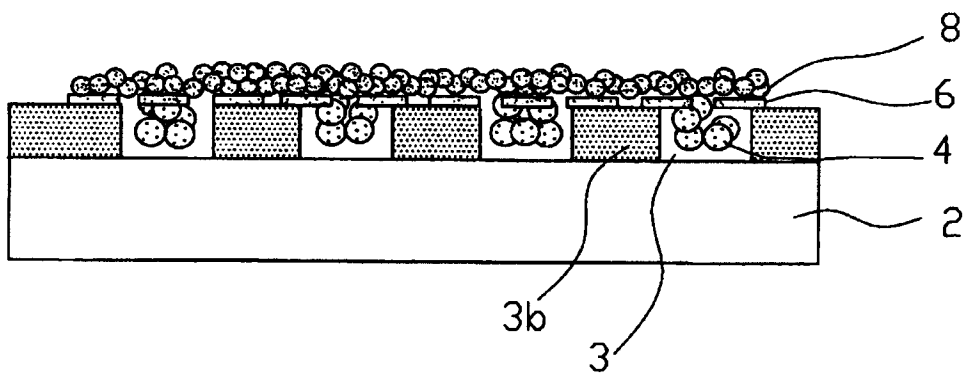




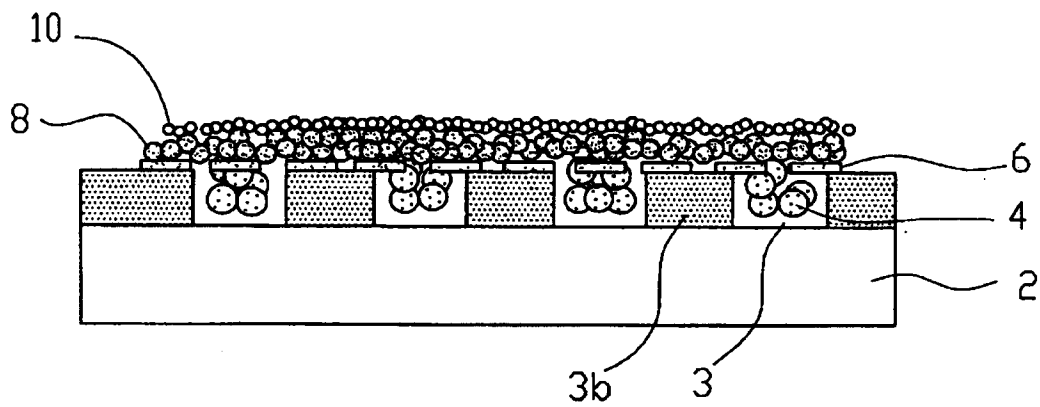
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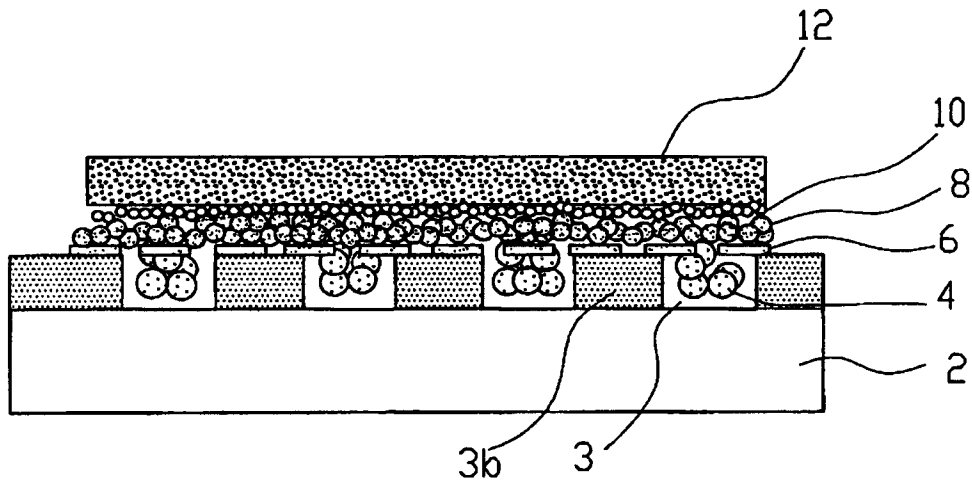
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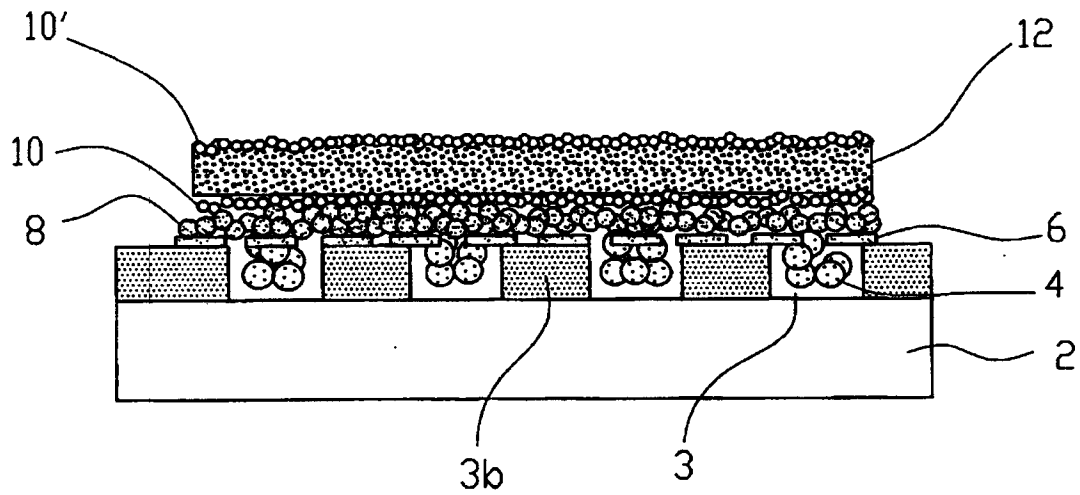
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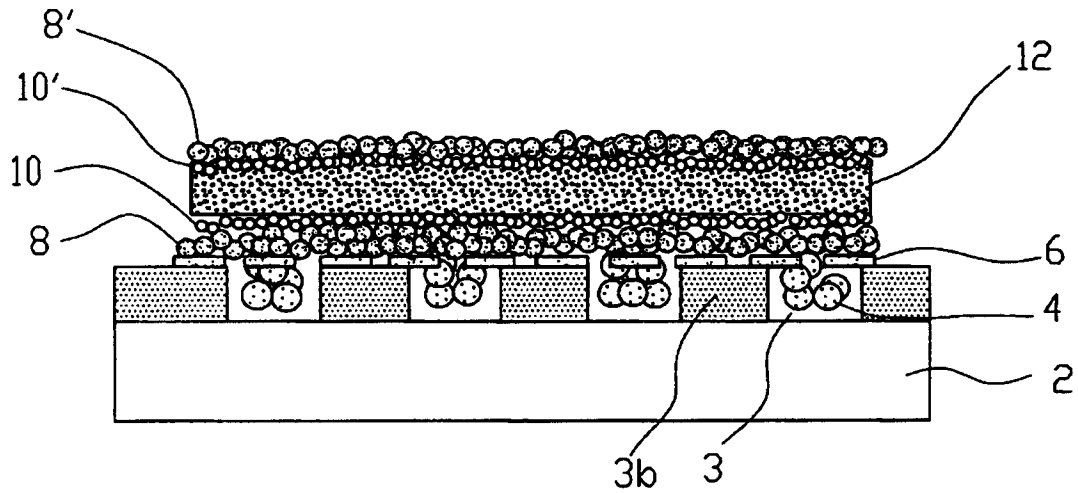
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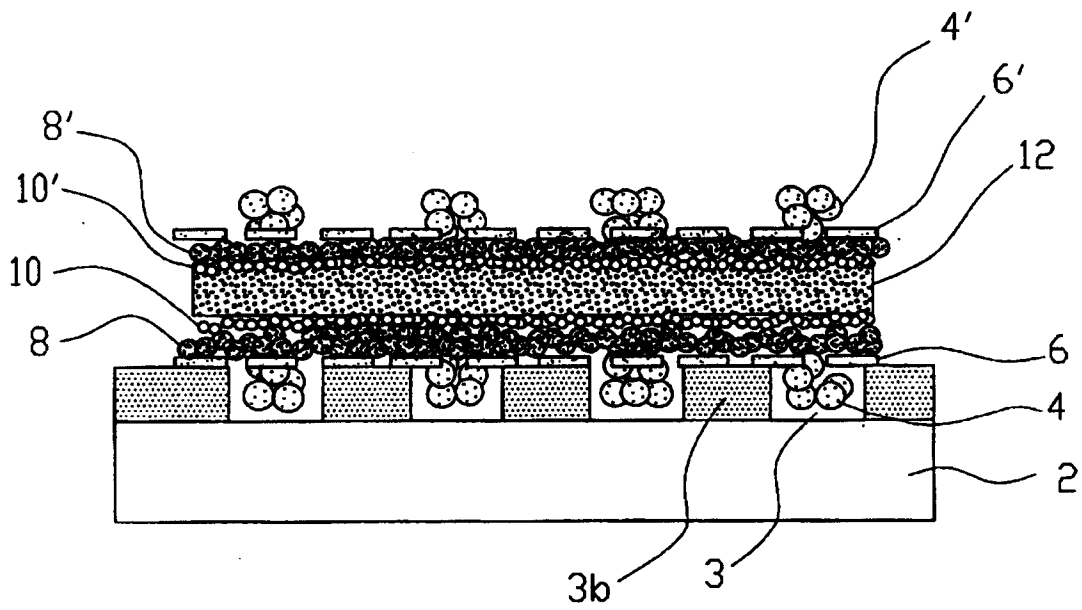
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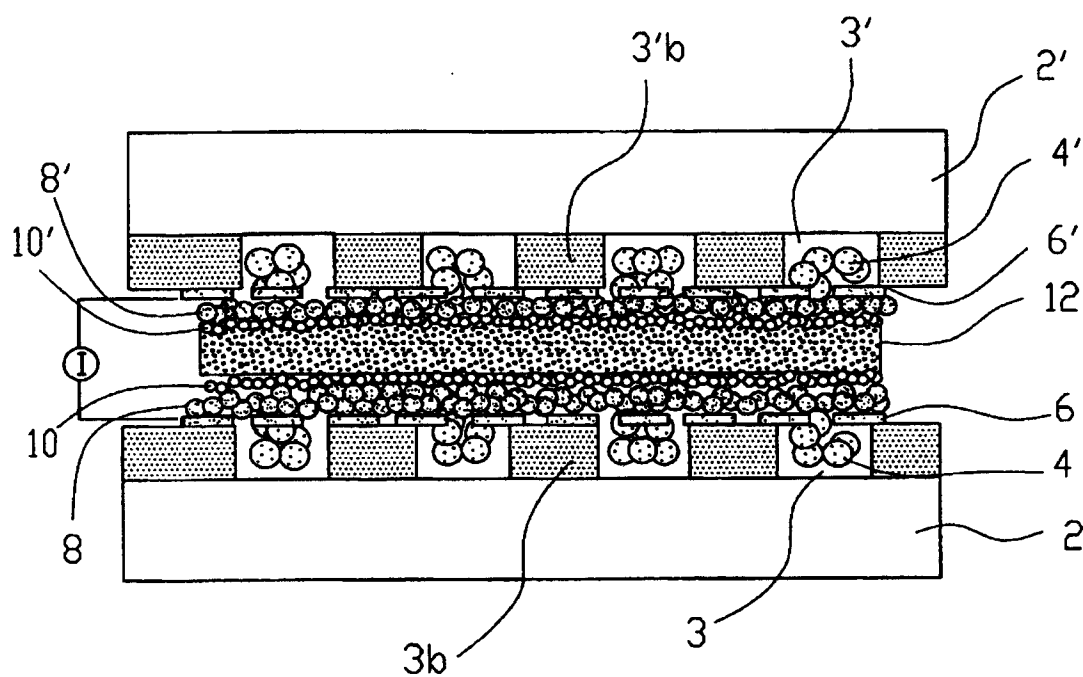
【図 14】



【図 15】



【図 16】



【図 17】

